The Development of a Manure Composting System for West Virginia Dairy Producers

James Simmons, Robert G. Diener
Layle Lawrence, William T. Jones
Kendall Elliott, Bradford Bearce
and Alan Collins

Bulletin 717 - 1998
West Virginia Agricultural
and Forestry Experiment Station
College of Agriculture, Forestry
and Consumer Sciences
West Virginia University

Authors

James Simmons is a Research Assistant with the Division of Resource Management, College of Agriculture, Forestry and Consumer Sciences, West Virginia University. **Dr. Robert G. Diener** is a Professor in the Division of Resource Management, College of Agriculture, Forestry and Consumer Sciences, West Virginia University. **Dr. Layle Lawrence** is a Professor and Chairperson of the Agricultural and Environmental Education Program in the Division of Resource Management, College of Agriculture, Forestry and Consumer Sciences, West Virginia University. **William T. Jones** is the Manager of the Animal Science Farms, College of Agriculture, Forestry and Consumer Sciences, West Virginia University. **Kendall Elliott** is a Professor Emeritus of Agricultural and Environmental Education in the Division of Resource Management, College of Agriculture, Forestry and Consumer Sciences, West Virginia University. **Dr. Bradford Bearce** is a Professor in the Division of Plant and Soil Sciences, College of Agriculture, Forestry and Consumer Sciences, West Virginia University. **Dr. Alan R. Collins** is an Associate Professor of Agricultural and Resource Economics in the Division of Resource Management, College of Agriculture, Forestry and Consumer Sciences, West Virginia University.

This research was sponsored by the West Virginia Agricultural and Forestry Experiment Station at West Virginia University. The authors wish to thank Mr. Lyle "Cam" Tabb, Jr., Leetown, WV, for his help and encouragement with this study.

West Virginia University
West Virginia Agricultural and Forestry Experiment Station
College of Agriculture, Forestry and Consumer Sciences
Rosemary R. Haggett, Dean and Director
1170 Agricultural Sciences Building
PO Box 6108
Morgantown, WV 26506-6108

Visit our Web Site at **http://www.caf.wvu.edu/**

The Development of a Manure Composting System for West Virginia Dairy Producers

James Simmons, Robert G. Diener,
Layle Lawrence, William T. Jones, Kendall Elliott,
Bradford Bearce and Alan Collins

Introduction

Dairy cattle manure can be a problem for farmers because of storage requirements, nuisance complaints, and excess nitrogen and phosphorous entering the groundwater, causing possible contamination of drinking water. Often farmers must transport this manure, which has a moisture content of between 80 and 95%, to remote locations for disposal because fields near the feed lot have generally become loaded with nitrogen and phosphorous.

However, dairy cattle manure can be made into a valuable soil amendment by composting. The composting process reduces volume, reduces moisture content, stabilizes nitrogen and produces a humus-like material. Composting can eliminate most of the handling and storage problems associated with animal manure. Finally, when compost is land applied, the soil porosity is increased, the efficiency of commercial fertilizers is enhanced and soil pH is raised.

While composting may seem a simple process, it requires careful thought and planning to compost large quantities of organic materials. Most dairy producers already have extensive facilities and equipment including manure pits, lagoons, tractors, front-end loaders and manure spreaders which can be used for composting. However, producers must learn the new composting technology and

procedures and also purchase or adapt existing equipment for this purpose.

Objectives

This study was designed to determine the most efficient procedure for composting dairy manure. The research was conducted at the West Virginia University Dairy Farm located on Stewartstown Road in Morgantown, WV.

Specific Objectives:

1. Convert existing pit and lagoon manure handling methods to composting technology.

2. Compare three windrow turning methods: static, windrow, front loader turned windrow, and windrow turning machine.

3. Determine chemical and physical properties of finished compost from the three experimental windrows.

Compost Technology

Composting is a biological process that requires mixing together of organic matter, water, microorganisms, and oxygen, in specific proportions (Figure 1, Table 1). This biological process produces heat, carbon dioxide, and a finished compost that can be used on agricultural cropland or further cured and screened for commercial sale.

Figure 1. The Composting Process (Rynk et al., 1992)

$$\boxed{\begin{matrix}\text{ORGANIC}\\\text{MATTER}\end{matrix}} + \begin{matrix}O_2\\H_2O\end{matrix} \xrightarrow[\text{actinomycetes fungi}]{\text{bacteria}} \boxed{\begin{matrix}\text{HUMUS,}\\\text{NITRATES,}\\\text{ORGANIC (N)}\\\text{PHOSPHATES}\end{matrix}} + \begin{matrix}CO_2\\H_2O\\\text{HEAT}\end{matrix}$$

The carbon, chemical energy, protein, and water in the finished compost are less than that in the raw materials. The finished compost has more humus. The volume of the finished compost is 50 percent or less of the volume of raw material.

Table 1. Ideal Conditions for Composting (Rynk et al., 1992)

Condition	Reasonable Range*	Preferred Range
Carbon to nitrogen (C/N) ratio	20 to 1 - 40 to 1	25 to 1 - 30 to 1
Moisture content	40 to 65%**	50 to 60%
Oxygen concentrations	Greater than 5%	Varies**
Particle size (diameter in inches)	1/8 - ½	Varies**
pH	5.5 - 9.0	6.5 - 8.0
Temperature (F)	110 - 150	130 - 140
Porosity (Voids)	33%	33%

*These recommendations are for *rapid* composting. Conditions outside these ranges can also yield successful results.

**Depends on the specific materials, pile size, and/or weather conditions.

Benefits of composting include: 1) pathogen and disease suppression (Logsdon, 1993; Pace et al., 1994; Hoitink et al., 1991); 2) increased soil conditioner (Bevacqua and Mellano, 1993; Jing and Barnes, 1993); 3) micro and macro nutrient benefits (van der Werf, 1993; Logsdon, 1995); 4) remediation (Brown et al., 1995; Cacciatore et al., 1995; Glaser et al., 1996); 5) a reduction in risk of pollution (properly prepared compost has an excellent water retention value and organic forms of nitrogen do not leach from the

soil); and 6) reduction of nuisance complaints (Rynk et al., 1992).

Previous Composting Studies

Limited research has been conducted on dairy manure composting. One study conducted by Fiorina et al. (1996) evaluated "the economics of on-farm composting as a manure management alternative to the spreading of raw manure and liquid manure storage systems, using four different livestock operations as case studies." Four farms in southeastern Pennsylvania were compared in ten different categories: 1) planning, permitting, and supervising tasks; 2) materials handled and their value; 3) site planning and land use; 4) tasks involved in collecting and receiving materials which were directly or indirectly added to the compost; 6) forming and 7) turning compost windrows; 8) shredding, mixing, and screening of the finished compost product; 9) monitoring and maintenance of site and equipment; and 10) utilization and marketing of the finished product.

Results concluded that collecting and spreading raw manure was the least expensive method for three farms and liquid manure storage for the hog farm was the least expensive for the fourth farm. However, composting became cost competitive when the revenues from compost sales were included. One farm profited from composting and one farm nearly broke even as compared to raw manure systems. "The majority of the costs for composting as a manure management method were in the materials collection area, for handling both on-farm (i.e., manure, straw, corn fodder) and off-farm (i.e., sawdust, rock dust, leaves, newspaper) materials." This study, however, did not consider other important benefits: 1) odor reduction; 2) micronutrient recovery; 3) hauling reduction; 4) reduction of nitrogen and phosphorus contamination of ground water;

5) water retention value of compost; 6) weed seed and pathogen destruction during composting; 7) reduction of neighbor complaints; and 8) sediment and water runoff reduction.

In-vessel dairy manure handling systems, including a tank system that composts liquid dairy cow waste (Hoffman and Crauer, 1973), bin composting (Wilson and Hummell, 1973; White, 1993), and a forced aeration batch composter (Hong et al., 1983) have been studied. Disadvantages of in-vessel systems were found to be: 1) large monetary investment required from the farmer to build and maintain; 2) required continued monitoring of the systems to insure a quality finished product; and 3) did not utilize the old manure handling system currently on the farm.

In West Virginia, a successful composting operation was established by Mr. Cam Tabb. Mr. Tabb operates a 1,600-acre dairy and crop farm near Leetown, WV. He began composting manure in 1991 because of disposal problems (Merrill, 1995). Since applying compost to his crop lands, he has eliminated or reduced the purchases of fertilizer, lime, herbicides and micronutrients. Mr. Tabb could not produce enough compost for application to all of his fields during a year.

Experimental Study at WVU

The composting system developed at the WVU Animal Science Farm used the existing manure pits for the primary operations, mixing and allowing some of the excess water to run off (Figure 2)[1]. Two pits were combined into a

---

[1]This system was based on procedures developed by Cam Tabb at his dairy farm in Leetown, WV.

single mixing and blending area. Manure was taken from the barn and placed in the pits where the manure was mixed with bulking and carbon sources. Excess moisture was allowed to drain off into a lagoon. After one or two weeks, the compost mixture was taken to the finishing area where the composting process was completed.

Wood chips were used for **bulking** and were supplied by Asplundh from tree cutting along rights of way for the power lines owned by Monongahela Power (now Allegheny Power). **Carbon source** material included leaves provided from the West Virginia University campus, shredded paper delivered to the farm, spoiled corn silage, and waste feed from the dairy cows.

The volume ratios (based on Table 1) of bulking agents, carbon sources, and animal manure in the compost mix are presented in Table 2. These ratios were modified based on the availability of materials, the amount of excess moisture, or for other needs. The material was mixed until the operator could dump out one bucket and the mixed material would remain in the shape of the bucket, representing an approximate moisture content of 60 to 75%.

Figure 2 - View of the new, combined manure pit at the

WVU Dairy Farm that is used for mixing, blending, and first heat stage composting.

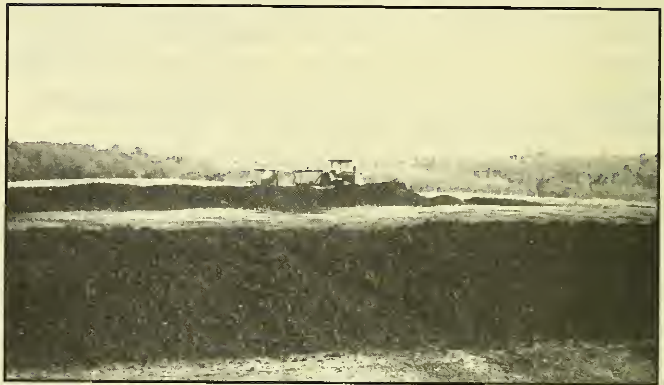


Figure 3 - View of the finishing area of the composting operation at the WVU Dairy Farm. The mixed material is removed from the manure pit, placed into windrows and monitored.

Table 2 - Materials Added in the Mixing Stage of Composting, Listed as a Ratio by Volume

Animal manure	1 volume
Bulking agent (wood chips)	1 volume
Carbon sources (leaves, corn silage, paper, and feed from the dairy cows that was not eaten)	2 volumes

The material would be left in the pit for one or two weeks, depending on the work load at the Dairy Farm, and then transferred into windrows in an adjacent area (Figure 3) to complete the composting. Three windrow treatments were studied:

1. **Static windrow** - A windrow was mixed and blended in the manure pit and then placed in the finishing area with a manure spreader and not turned throughout the experiment.

2. **Front loader turned windrow** - A windrow was mixed and blended in the manure pit and then placed in the finishing area with a manure spreader and turned with a front-end loader. The windrow was turned when the temperature rose above 145 degrees Fahrenheit or dropped below 100 degrees Fahrenheit.

3. **Windrow turning machine windrow** - A windrow was mixed and blended in the pit, then placed in the finishing area with a manure spreader and turned with a Sittler 1012 windrow turner. The windrow was turned when the temperature was over 145 degrees Fahrenheit or below 100 degrees Fahrenheit.

All windrows were formed in the first three weeks of August 1995. Each windrow, approximately 4 feet high, 13 feet wide and 25 feet in length, was made with five manure spreader loads (one manure spreader volume was approximately 343 bushels).

Results

All dairy manure produced on the farm for the last year and a half has been successfully composted using the procedure developed in this study. There was a noticeable reduction in fly problems in the manure pit area.

Composting reduced nitrogen from ammonia forms to protein or slow-release forms as shown in Table 3. Total nitrogen in manure was generally conserved by the composting process and made less prone to runoff by converting it to an organic form.[2] The C/N ratio decreased for all windrow treatments as excess carbon was "burned off" in the form of CO_2 gas. pH increased as high as 8.6 in the finished product as a result of microbiological action.

Table 3 - Results of the Three Windrow Composting Treatments

	Raw Manure	Static Windrow Compost	Front Loader Turned Windrow Compost	Windrow Turning Machine Compost
TKN	2.84%*	3.36%	2.72%	3.04%
Nitrate-Nitrogen	49.0 ppm	640.0 ppm	204.0 ppm	124.0 ppm
Ammonia-Nitrogen	9,300.0 ppm	40.5 ppm	59.0 ppm	230.0 ppm
C/N Ratio	15/1	10/1	12/1	12/1
pH	5.7	7.6	7.5	8.6
Volume	1.00	0.68	0.43	0.39
Bulk Density	54.06 lbs/cf**	34.34 lbs/cf	34.84 lbs/cf	23.91 lbs/cf
Moisture Content (w.b.)***	82%	69%	59%	40%

* of dry matter
** cubic foot
*** wet basis

---

[2]It should be generally recognized that there is a net nitrogen loss during composting due to ammonia and other losses. However, a corresponding greater loss of organic matter as CO_2 actually *raises* the results of total nitrogen which is measured as percentage of dry matter.

Composting had generally favorable results on pH, volume and weight reduction and lowering of moisture content. Weight reduction resulted from lowering moisture content and "burning off" carbon. This resulted in a product which is much easier to spread and requires about half the number of trips to the field.

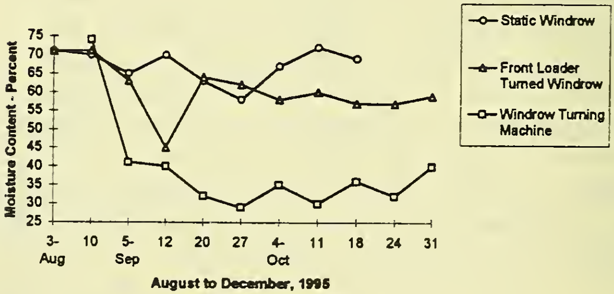
Effect of Windrow Turning Method

Machine Turned Windrow - The compost that was turned produced the best finished compost. This method completed composting in the shortest amount of time, had the greatest reduction in weight (bulk, density), reduced volume over 40%, and finished with the lowest moisture content of 40% (Table 3). The compost also exceeded the Environmental Protection Agency regulation, Part 503, Standards for the Process to Further Reduce Pathogens (PFRP). Temperatures were above 55 degrees Celsius (131 degrees Fahrenheit) for more than 15 days through the months of August into September. During this period of time there were required to be a minimum of five windrow turnings (one every three days).

Front Loader Turned Windrow - The front loader turned windrow compost produced lower temperatures than the machine turned windrow, less reduction in the weight (bulk density) and the volume and moisture content (Table 3). With this treatment, the outer surface of the windrows can form a hard crust which retards air and moisture movement. Thus, composters need to make decisions about turning the windrows, taking into consideration: 1) temperatures, 2) condition of the outer surface, and 3) how much precipitation has fallen. Additional planning will assure that the entire pile has the same moisture content and composting continues evenly throughout the windrow.

Another problem with the front loader turned windrow was that the center of the windrow was not turned. The operator would push the windrow to the left or right, pushing material over the top of the windrow but seldom reaching the interior of the core of the windrow. In this case, the core of these windrows may cease composting and undergo anaerobic respiration, producing ammonia, methane, leachate and other unwanted products.

Figure 4 - Moisture Content Percentage of the Three Composting Treatments



Unturned (Static) Windrow - The static windrow was not blended or mixed thoroughly, had the lowest temperatures, required the longest time to reach a finished compost, but required the least amount of labor for maintenance and monitoring. The static windrow may be satisfactory for farmers: 1) who are interested in applying the finished compost to the fields rather than marketing the finished product; 2) have plenty of time and land space to allow the material to finish composting; or 3) do not want to spend a lot of time monitoring or turning the windrows.

Heavy Metal Consideration

Levels of heavy metals in the experimental windrows are shown in Table 3. These windrow levels fall far below the EPA maximums listed in Part 503, thus the compost is safe for field application. Metals concentrate (increase) from composting because of the reduction of dry matter.

Table 4 - Comparison of EPA Regulations for Heavy Metals with the Sampled Material from the Experiment

	US-EPA Limit (Part 503, 1992)*	Manure	Static Windrow	Bucket Turned Windrow	Machine Turned Windrow
Arsenic	41.00**	<2.00	2.30	3.30	4.10
Cadmium	39.00	0.20	<0.20	<0.20	<0.20
Chromium	1,200.00	13.90	61.70	70.20	34.80
Cobalt	-***	-	-	-	-
Copper	1,500.00	51.40	58.60	54.60	39.80
Lead	300.00	5.90	2.60	4.50	5.70
Mercury	17.00	<1.00	<1.00	<1.00	<1.00
Molybdenum	18.00	2.60	7.90	8.10	4.10
Nickel	420.00	8.20	66.50	83.50	43.70
Selenium	36.00	0.12	0.65	0.68	0.46
Zinc	2,800	283.50	771.10	721.60	267.20
PCB	-	-	-	-	-

* Code of Federal Regulations: Title 40, Chapter 1, Sub-Chapter 0, Sewage Sludge, Part 503 - Standards for the Use and Disposal of Sewage Sludge, November 25, 1992.

** Parts per million of dry matter.

*** Indicates values were not listed.

Summary

Composting of dairy manure can be done at minimal cost and using existing farm equipment with the exception of a PTO windrow turner which costs approximately $15,000, delivered for this study.

Composting of dairy manure produced a product which is dry (40% moisture content for machine turned windrows) enough to pile and spread easily. Nitrogen content was stabilized at around 3% in a slow release form and pH was raised to 7.5 to 8.5. In addition, the high temperatures during composting are reported to kill weed and other seeds. Heavy metals content of manure and manure compost was well below US-EPA Part 503 standards (for use and land application of sewage and sludge).

Static windrow treatment produced finished compost material, but the structure was coarse and non-homogenous and could not be screened. Windrows which were bucket turned finished sooner and had a more homogenous mix and greater volume reduction. However, machine turned windrows produced the best compost from the standpoint of speed, volume, mass and moisture reduction. It was the only product which could easily be screened for commercial sales.

Composting of dairy manure makes a valuable soil amendment and can be applied for general use to agricultural croplands, turf, home gardens and golf courses. This material could also be blended to make potting soil, top soil, or "cow manure mulch" for commercial sale.

Bibliography

Bevacqua, R.F. and Mellano, V.J. (1993, July). Sludge Compost Boosts Yields of California Crops. BioCycle. 78-79.

Brown, K.W., Thomas, J.C., and Seago, O.J. (1995, September). Degradation of Explosive Propellants by In-vessel Composting. BioCycle. 56-58.

Cacciatore, D.A. and McNeil, M.A. (1995, October). Implementing the Concepts and Principles of Soil Bioremediation. BioCycle. 61-64.

Fiorina, L.J., Oshins, C., and Weber, J. Economic Feasibility of Agricultural Composting as a Manure Management Alternative: Four Case Studies. Penn State/Rodale Institute. 1/17/1996.

Glaser, J.A. and Protter, C.L. (1996, January). Soil Bioremediation Research at EPA. BioCycle. 50-53.

Hoffman, B. and Crauer, L.S. (1973, February). Liquid Composting of Dairy Cow Waste. National Dairy Housing Conference. 429-440.

Hoitink, H.A.J., Inbar, Y., and Boehn, M.J. (1991). Status of Compost-Amended Potting Mixes - Naturally Suppressive to Soil-Borne Diseases of Floriculture Crops. Plant Dis 75(9):869-876.

Hong, J.H., Matsuda, J., and Ikeuchi, Y. (1983). High Rapid Composting of Dairy Cattle Manure With Crop and Forest Residues. Transactions of the American Society of Agricultural Engineers. 533-545.

Jing, J. And Barnes, S. (1993, November). Agricultural Use of Industrial Byproducts. BioCycle. 63-64.

Logsdon, G. (1995, October). Compost is Key to Theme Park's Beauty. BioCycle. 48-50.

Logsdon, G. (1993, October). Using Compost for Plant Disease Control. BioCycle. 33-36.

Merrill, L.S. (1995, April 25). He Makes and Uses His Own Composted Manure. Hoard's Dairyman. 315.

Pace, M.G., Miller, B.E., and Miller, R.L. (1994). Weed Seed Viability in an Animal Waste Composting System. Presentation at the 1994 International Winter Meeting Sponsored by the American Society of Agricultural Engineers. #941594.

Part 503 Standards for the Use and Disposal of Sewage Sludge. November 25, 1992.

Rynk, R., van de Kamp, M., Wilson, G.B., Singley, M.E., Richard, T.L., Kolega, J.J., Gouin, F.R., Laliberty, Jr., L., Kay, D., Murph, D.W., Hoitink, H.A.J., and Rinton, W.F. (1992). On-farm Composting Handbook. New York: Northeast Regional Agricultural Engineering Service.

van der Werf, P. (1993, February). Compost as a Partial Nutrient Source. BioCycle. 79.

White, T. (1993, April). Waste Not: Composters Add Value to Manure. Ohio Farmer. 8-10.

Wilson, G.B. and Hummel, J.W. (1973). Solid Composting of Dairy Manure. National Dairy Housing

Conference. American Society of Agricultural Engineers. 441-459.

Notes

Notes

Notes

West Virginia University
West Virginia Agricultural and
Forestry Experiment Station
College of Agriculture, Forestry
and Consumer Sciences
1170 Agricultural Sciences Bldg.
PO Box 6108
Morgantown, WV 26506-6108

Non-Profit Organization
U.S. Postage
PAID
Morgantown, WV
Permit No. 34